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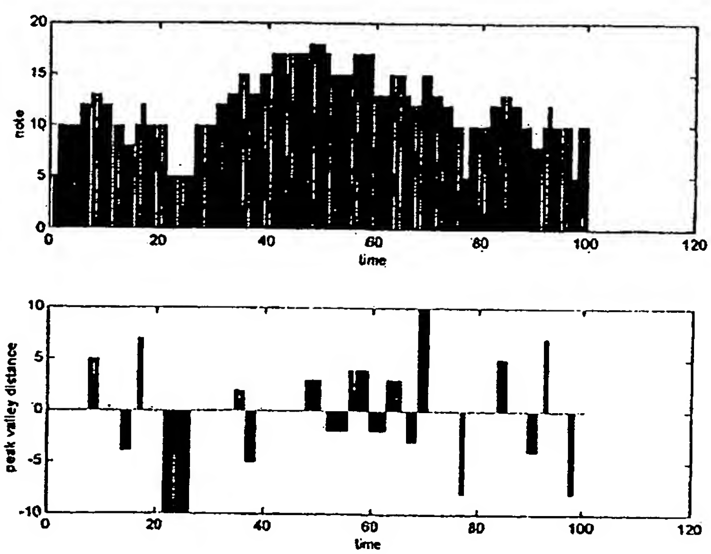
(54) Title: METHOD AND SYSTEM OF REPRESENTING MUSICAL INFORMATION IN A DIGITAL REPRESENTATION FOR USE IN CONTENT-BASED MULTIMEDIA INFORMATION RETRIEVAL



Score Melody Processing

(57) **Abstract:** The invention relates to content-based audio/musing retrieval and other content-based multimedia information retrieval. In one aspect the present invention provides a method of representing audio/musical information in a digital representation suitable for use in content-based information indexing and retrieval including the steps of: determining a first representation including a set of peaks and valley corresponding to maximum and minimum values respectively of at least one characteristic of the audio/music, and; determining a second representation including values representing relative differences between peaks and valleys. The invention presents a method and a system for content-based music retrieval. A musing score database is constructed to provide a unique representation of real music songs. Score keywords are extracted from the music score as the features of the musing songs. This invention also provides a method to automatically convert the queries inputted by humming into query keywords. The extracted query keywords will be matched with the existing score keywords in the music score database to retrieve the relevant music songs. Since there is an exact correspondence between the music scores and actual music songs, the retrieval accuracy will be greatly improved compared with other low-level feature based music retrieval methods.

WO 03/005242 A1

Method and System of Representing Musical Information in a Digital Representation for use in Content-based Multimedia Information Retrieval

FIELD OF INVENTION

This invention relates to content-based audio/music retrieval and other content-based multimedia information retrieval where the multimedia information includes audio/music.

BACKGROUND OF INVENTION

The rapid development of computer networks and the technologies related to Internet have resulted in a rapid increase of the size of digital multimedia data collections. How to effectively organize such information to allow efficient browsing, searching and retrieval has been an active research area in the past decades and still is. Various kinds of content-based image and video retrieval methods have been developed since the early 1990's. The accuracy and speed are two important index performances to evaluate a retrieval method. Compared with the content-based image and video retrieval, content-based audio retrieval, especially music retrieval, provides a special challenge because a raw digital audio data is a featureless collection of bytes with most rudimentary fields attached such as name, file format, sampling rate, which does not readily allow content-based retrieval. Current content-based audio retrieval methods followed the same ideas as with the content-based image retrieval. Firstly, a feature vector is constructed by extracting acoustic features of audio in the database. Secondly, the same features are extracted from the queries. Finally, the relevant audio in the database is ranked according to the feature matching between the query and the database.

U.S. Pat. No. 5,918,223 discloses a system that performs analysis and comparison of audio files based upon the content of the data files. The analysis of the audio data produces a set of numeric values (a feature vector) that can be used to classify and rank the similarity between individual audio files typically stored in a multimedia database or on the World Wide Web. The analysis also facilitates the description of user-defined classes of audio files, based on an analysis of a set of audio files that are members of a user-defined class. The

system can find sounds within a longer sound, allowing an audio recording to be automatically segmented into a series of shorter audio segments.

The publication entitled "Content-based Classification and Retrieval of Audio Using the Nearest Feature Line Method" by Stan Z. Li (IEEE Transactions on Speech and Audio Processing, Accepted, 1999) discloses a method for content-based audio classification and retrieval. It is based on a new pattern classification method called the nearest Feature Line (NFL). In the NFL, information provided by multiple prototypes per class is explored. This contrasts to the nearest the nearest neighbor (NN) classification in which the query is compared to each prototype individually. Regarding audio representation, perceptual and cepstral features and their combinations are considered.

The publication entitled "Content-based Retrieval of Music and Audio" by J. Foot (Proc. of SPIE, Vol.3229, 1997, pp. 138-147) discloses a method to use 12 mel-frequency cepstral coefficients (MFCCs) plus energy as the audio features. A tree-structured vector quantizer is used to partition the feature vector space into a discrete number of regions or "bins". Euclidean or Cosine distances between histograms of sounds are compared and the classification is done by using NN rule.

One problem with existing methods is that these are considered to fail to obtain a satisfactory retrieval accuracy rate because of the noise is introduced in the process of feature extraction. Furthermore, it is considered that prior art methods are time-consuming if the feature vector space becomes large.

SUMMARY OF INVENTION

In one aspect the present invention provides a method of representing audio/musical information in a digital representation suitable for use in content-based information indexing and retrieval including the steps of: determining a first representation including a set of peaks and valleys corresponding to maximum and minimum values respectively of at least one characteristic of the audio/music, and; determining a second representation including values representing relative differences between peaks and valleys.

In another aspect the present invention provides a method of creating an audio/music score database, including the steps of: using an audio/music score to

uniquely represent an actual music song such that there is a link provided between an audio/music score database and an audio/music database; using a curve including a set of digital values to represent the audio/music score, and; using peaks and valleys of the curve for indexing the audio/music score database.

In yet another aspect the present invention provides a method of converting an audio/music score into score keywords, including the steps of: pre-processing a score curve to remove zero notes, the score curve including a set of digital values representing audio/musical notes; detecting peaks and valleys of the score curve; calculating the distance between each peak/valley and valley/peak pair; using the peaks and valleys as reference points, and a note histogram of the peaks and valleys to serve as score keywords.

In still another aspect the present invention provides a system for use in content-based information retrieval operating in accordance with a method as described above.

In essence, the present invention stems from the realisation that a representation of audio/musical information, which includes a characteristic relative difference value, provides a relatively accurate and speedy means of representing, indexing and/or retrieving content-based audio/musical information. It has also been found that these relative difference values provide a relatively non-complex feature representation.

In a preferred embodiment, the method of the present invention further includes the step of determining a histogram of the first representation.

Preferably, the histogram of the first representation includes a representation of, the population, or duration, of peaks or valleys in a given time interval.

Preferably, the relative difference value for a peak is given by the difference between the magnitude of a valley immediately following the peak and the magnitude of the peak, and, the relative difference value of a valley is given by the difference between the magnitude of a peak immediately following the valley and the magnitude of the valley.

In another preferred embodiment, the method of the present invention further includes the step of determining a histogram of the second representation.

Preferably, the audio/musical information is a music score. In this embodiment, the method of the present invention further includes the step of pre-processing the music score before performing the step of determining the first representation, which includes removing zero notes from the music score, and, adjoining the remaining nonzero notes to fill any gaps left by the removed zero notes.

Preferably, the audio/musical information is an acoustic signal and, the acoustic signal may be a vocal or humming signal. In this embodiment, the method of the present invention includes the step of pre-processing the acoustic signal before performing the step of determining the first representation, which includes converting the acoustic signal to a digital signal; removing noise from the digital signal; subjecting the noise free digital signal to pitch detection; and, subjecting the pitch detected digital signal to interval or note detection. The pitch detection includes a windowed Fourier transform and auto-correlation of the noise free digital signal. The interval or note detection includes logarithmically scaling the pitch detected digital signal.

Preferably, the characteristic of the audio/music is any one or more of the following: volume level; pitch; or interval information.

In another preferred embodiment the present invention provides a method of creating a music score database, including the steps of: representing an actual music track uniquely with a music score such that there is a link between the music score and the actual music track; representing the music score in accordance with a method as described above to form search keywords; and, storing the search keywords in a database.

In a preferred embodiment of the present invention, the method of creating a music score database further includes the step of creating at least one index for storage with the database, the at least one index including a global feature corresponding to an entire music score wherein the global feature includes the histogram of the second representation.

In another preferred embodiment the present invention provides a method of creating a query keyword from an acoustic input for retrieval of music information in a music score database including the step of representing the acoustic input in a digital representation in accordance with a method as described above.

In yet another preferred embodiment, the present invention provides a method of retrieving music information from a music score database created in accordance with the method of creating a music score database as described above by matching query keywords with database keywords including the steps of: comparing a query keyword, created in accordance with the method of creating a query keyword as described above, with the global feature corresponding to each music score to eliminate non-relevant database keywords; comparing the second representation of the query with the second representation of each database keyword; comparing the histogram of the first representation of the query with the histogram of the first representation of each database keyword.

In a preferred embodiment, the present invention provides a method of creating indexes to organise the music score database including the step of: constructing a global feature for the complete actual music song, wherein the global feature is the histogram of the values of the distances between each peak/valley and valley/peak pair.

In yet another preferred embodiment, the present invention provides a method of automatically converting acoustic input in the form of humming into query keywords, including the steps of: converting the acoustic input into a digital signal; detecting the pitch from the digital signal; converting the pitch into notes; representing the acoustic input by a pitch curve; smoothing of the pitch curve by removing small peaks and valleys; detecting peaks and valleys of the pitch curve; generating the query keywords using the peaks and valleys in accordance with the following steps:

- calculating the distance between each peak/valley and valley/peak pair; and,
- using the peaks and valleys as reference points, and a note histogram of the peaks and valleys to serve as score keywords.

BRIEF DESCRIPTIONS OF THE DRAWINGS

These and other features and advantages of the present invention will be readily apparent to one of ordinary skill in the art from the following written description, used in conjunction with the attached drawings, in which:

Fig. 1 illustrates the system structure of the communications between the server and the client in a music database retrieval system using the present invention.

Fig. 2 illustrates the structure of the music score database of Fig. 1.

Fig. 3 illustrates the block diagram of the score database construction.

Fig. 4 illustrates the score melody processing done in the score database construction.

Fig. 5 illustrates a flowchart of the score/pitch keyword extraction.

Fig. 6 (a) to (c) illustrate a piece of music score, the melody contour, and an example of the extracted score keywords.

Fig.7 illustrates a flowchart of the query processing and keyword extraction.

Fig.8 illustrates a flowchart of the pitch melody processing done in the query processing.

Fig. 9 (a) to (c) illustrate a digital query signal, the detected pitch and interval contour, and an example of the extracted score keywords.

Fig. 10 (a) to (c) illustrate another digital query signal, the detected pitch and interval contour, and an example of the extracted score keywords.

Fig. 11 illustrates a block diagram of a method of matching between the score keywords and the query keywords.

Fig.12 illustrates a flowchart of the matching algorithm.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. 1 illustrates the system structure of the communications between the client and server. There are one or several music databases at the server to store digital music contents. There is a music score database including the score keywords corresponding to each music database. The services in the server side include receiving queries from the clients, matching query keywords with score keywords in the music score databases, retrieving the relevant music songs and

sending them to the clients. The services in the client side include music search engine, query processing, and music browsing. The user can input his or her humming to the music search engine through the microphone. The query-processing module will extract the query keywords from the query and send the query keywords to the server through the Internet. When the server sends back the retrieved music songs to the client, the music-browsing tool will enable the user to view these songs clearly and listen to them easily.

Fig. 2 illustrates the structure of the music score database. The music score database corresponds to the music database that includes the actual music songs. The fields of a record in the music score database include music title, singer, music type, score keywords, and a linkage to the actual music stored in the music database.

Fig. 3 illustrates a block diagram of score database construction. It consists of 3 steps: score melody processing, score keywords generation, and score keywords indexing.

The input to this module is the music score corresponding to a music song, which may also be inserted into music database. The music score provides the composite information of the music and is available once the musical artists create the music. The music score basically specifies what note is played at what time for how long. Thus the music score can be easily represented in digital form. We represent each note by an integer, and a larger integer corresponds to a higher note. The distance between two adjacent notes is 1 semitone, and the distance between the two integers representing the two notes is also 1. The time information of each note is measured in an integer multiples of quarter-beat (or finer unit).

The music score information is processed by the score melody processing module followed by keyword generation module. The two modules will be illustrated by individual figures (Fig 4 and Fig 5). After the score keywords are extracted, they can be indexed for the purpose of efficient storage and searching of the score database.

Fig. 4 illustrates the flowchart of the score melody processing module. Music scores are firstly, in pre-processing, transformed into a curve, with x-axis

being time and y-axis being note levels. Since only relative note changes are important, the absolute value of each note is neglected. In music scores, there is a zero (0) note, which represents silence. The 0 notes are removed from the score curve, the notes ahead and behind the removed 0 note are simply connected. Secondly, the peaks and valleys of the score curve are detected. A peak is defined as a note being higher than both of the two notes connected to it ahead and behind. And similar is the definition of a valley. These peaks and valleys are very important feature points used for the indexing and retrieval of the music. An example of score curve and its peaks and valleys are illustrated in Fig 6 (a).

Fig. 5 illustrates the flowchart of the score keywords generation. After the peaks and valleys of the score curve are detected, for each peak and each valley, a value is calculated. For a peak, the value is the difference between its immediate following valley and itself, and the value is positive. For a valley, the value is the difference between its immediate following peak and itself, and it is a negative value. The sequence of values of the peaks and valleys are the first part of the features used in music retrieval. The lower picture in Fig 6 (a) shows the peaks and valleys together with their associated values.

Then the note histogram is calculated for each peak and valley. The note histogram contains information of how many or how long a note is presented during a time interval. The time interval can be a constant time duration or from the starting peak/valley to the x^{th} peak/valley that follow it. Fig 6 (c) shows the note histogram for the first peak in the example. We have in our example used the interval from a peak/valley to the 4^{th} valley/peak.

The feature values of the peaks and valleys of a complete song can also be statistically stored in a histogram and used as a global feature of the music. It can be used as the first step in the matching. If there is no match between the histogram and the searched music, then the further matching of other features is not necessary. This can speed up the searching process.

Fig. 6 (a) is an example score curve corresponding to a piece of a music score. The detected peaks and valleys and their feature values are also shown. Fig. 6 (b) is the detected peaks/valleys for the complete piece of music. The

figure at the bottom shows the global feature, which is the histogram of the peak/valley feature values. Fig. 6 (c) is the extracted score keywords corresponding to the first peak of the score curve. In this figure, the origin of the histogram is 6, which means the bin 6 corresponds to the note value of the starting note (first peak in this example).

Fig. 7 illustrates a block diagram of query keywords extraction. The query inputted by humming is an acoustic signal. It is converted to a digital signal via the A/D conversion device such as sound card. The digital signal passes through a pre-processing mechanism to remove the environment noise. Then pitch detection and interval detection are applied to the processed digital signal. In order to get a smooth pitch and interval contour, a pitch melody processing is conducted to the extracted pitch and interval information. Finally, the query keywords are generated according to the pitch and interval contour.

The pitch detection is done by windowed Fourier transform and auto-correlation.

The interval detection or note detection by logarithmically scaling of the detected pitch values. After note detection, the temporal change in the note value is comparable to the temporal change in the score note value. The inputted humming query can then be represented in a pitch curve. Further feature extraction can be done on this pitch curve.

The pitch melody processing detects the peak/valleys in the pitch curve, just as those for the score curve (Fig. 8).

The final query keyword generation is done using the same process as for score curve, which is shown in Fig. 5.

Fig. 8 illustrates the flowchart of the pitch melody processing. The pitch curve is smoothed firstly by removing small value changes. Then peak/valley detection is conducted on the smoothed pitch curve. Similar to the indexing process, or score keyword processing, the query keyword extraction also calculates the peak/valley values changes and the note histogram. These features are then used in the matching process.

Fig. 9 (a) is a digital query signal converted from humming the same as the piece of music score in Fig. 6 (a). Fig. 9 (b) is the detected pitch and interval

contour from Fig. 9 (a). The detected peak/valley values are also shown. Fig. 9 (c) is the extracted pitch keywords according to the information of Fig. 9 (b).

Fig.10 (a) is another digital query signal converted from humming the same as the piece of music score in Fig. 6 (a). Fig.10 (b) is the detected pitch and interval contour from Fig. 10 (a). The corresponding peak/valley values are also shown. Fig. 10 (c) is the extracted score keywords according to the information of Fig. 10 (b). From Fig. 9, Fig.10 and Fig. 6, it can be seen that either the score/pitch contours or the query keywords and the score keywords are similar.

Fig. 11 illustrates the block diagram of matching between the score keywords and the query keywords. The extracted query keywords will be compared with the score keywords in the database by use of a matching algorithm. The retrieval results will be ranked according to the similarity between the query keywords and score keywords and fed back to the users.

Fig. 12 shows the steps in the keyword matching. In step 1, the detected peak/valley values from query are compared to those of the score keyword. The comparison is then by measuring the cumulated distance of the peak/valley values. If the distance is less than a threshold, further similarity measure is done; otherwise, the matching should skip to next candidate. The difference is measured for a sequence of peak/valley values, say 5 values, and the difference for the 5 values are summed to form the final distance, which is then compared with the threshold.

In step 2, the note histograms are compared. Histogram intersection can be used to measure the similarity between the query and the candidate. The similarity can be ranked to list the search result in an order from most similar to least similar.

THE CLAIMS

1. A method of representing audio/musical information in a digital representation suitable for use in content-based information indexing and retrieval including the steps of:

   a) determining a first representation including a set of peaks and valleys corresponding to maximum and minimum values respectively of at least one characteristic of the audio/music;

   b) determining a second representation including values representing relative differences between peaks and valleys.

2. A method as claimed in claim 1, further including the step of:

   c) determining a histogram of the first representation.

3. A method as claimed in claim 2, wherein the histogram of the first representation includes a representation of, the population, or duration, of peaks or valleys in a given time interval.

4. A method as claimed in claim 1, wherein the relative difference value for a peak is given by:

   the difference between the magnitude of a valley immediately following the peak and the magnitude of the peak, and;

   the relative difference value of a valley is given by:

   the difference between the magnitude of a peak immediately following the valley and the magnitude of the valley.

5. A method as claimed in claim 1, further including the step of:

   d) determining a histogram of the second representation.

6. A method as claimed in claim 1, wherein the audio/musical information is a music score.

7. A method as claimed in claim 6, including the step of pre-processing the music score before performing step a), which includes:

removing zero notes from the music score, and;

adjoining the remaining nonzero notes to fill any gaps left by the removed zero notes.

8. A method as claimed in claim 1, wherein the audio/musical information is an acoustic signal.

9. A method as claimed in claim 8, wherein the acoustic signal is a vocal or humming signal.

10. A method as claimed in claim 8, including the step of pre-processing the acoustic signal before performing step a), which includes:

converting the acoustic signal to a digital signal;

removing noise from the digital signal;

subjecting the noise free digital signal to pitch detection;

subjecting the pitch detected digital signal to interval or note detection.

11. A method as claimed in claim 10, wherein the pitch detection includes a windowed Fourier transform and auto-correlation of the noise free digital signal.

12. A method as claimed in claim 10, wherein the interval or note detection includes logarithmically scaling the pitch detected digital signal.

13. A method as claimed in claim 1, wherein the characteristic of the audio/music is any one or more of the following:

volume level;

pitch;

interval information.

14. A method of creating a music score database, including the steps of:

representing an actual music track uniquely with a music score such that there is a link between the music score and the actual music track;

representing the music score in accordance with a method as claimed in claim 6, to form search keywords;

storing the search keywords in a database.

15. A method as claimed in claim 14, further including the step of:

creating at least one index for storage with the database, the at least one index including a global feature corresponding to an entire music score wherein the global feature includes the histogram of the second representation.

16. A method of creating a query keyword from an acoustic input for retrieval of music information in a music score database including the step of:

representing the acoustic input in a digital representation in accordance with the method as claimed in claim 8.

17. A method of retrieving audio/music information from a music score database created in accordance with the method as claimed in claim 14, by matching query keywords with database keywords including the steps of:

a. comparing a query keyword created in accordance with the method of claim 16, with the global feature corresponding to each music score to eliminate non-relevant database keywords;

b. comparing the second representation of the query with the second representation of each database keyword;

c. comparing the histogram of the first representation of the query with the histogram of the first representation of each database keyword.

18. A method of creating a music score database, including the steps of:

(a) using a music score to uniquely represent an actual music song such that there is a link provided between a music score database and music database;

(b) using a curve including a set of digital values to represent the music score information, and;

(c) using peaks and valleys of the curve for indexing the music score database.

19. A method of converting a music score into score keywords, including the steps of:

(a) pre-processing a score curve to remove zero notes, the score curve including a set of digital values representing musical notes;

(b) detecting peaks and valleys of the score curve;

(c) calculating the distance between each peak/valley and valley/peak pair;

(d) using the peaks and valleys as reference points, and a note histogram of the peaks and valleys to serve as score keywords.

20. A method of creating indexes to organise a music score database created in accordance with a method as claimed in claim 18, including the step of:

a. constructing a global feature for the complete actual music song, wherein the global feature is the histogram of the values of the distances between each peak/valley and valley/peak pair.

21. A method of automatically converting acoustic input in the form of humming into query keywords, including the steps of:

a. converting the acoustic input into digital signal;

b. detecting the pitch from the digital signal;

c. converting the pitch into notes ;

d. representing the acoustic input by a pitch curve;

e. smoothing of the pitch curve by removing small peaks and valleys;

f. detecting peaks and valleys of the pitch curve;

g. generating the query keywords using the peaks and valleys in accordance with steps c) and d) of claim 19.

22. A method of matching the query keywords of claim 21, with the music score keywords of claim 19, including the steps of:

a. checking a global feature constructed in accordance with a method as claimed in claim 20, to eliminate non-relevant music score keywords;

b. matching the sequence of peak/valley distance values of the query and the peak/valley distance values of the music score keywords;

c. matching the note histogram by histogram intersection.

23. A system for use in content-based information retrieval operating in accordance with a method as claimed in claim 1.

24. A system for use in content-based information retrieval operating in accordance with a method as claimed in claim 18.

25. A system for use in content-based information retrieval operating in accordance with a method as claimed in claim 19.

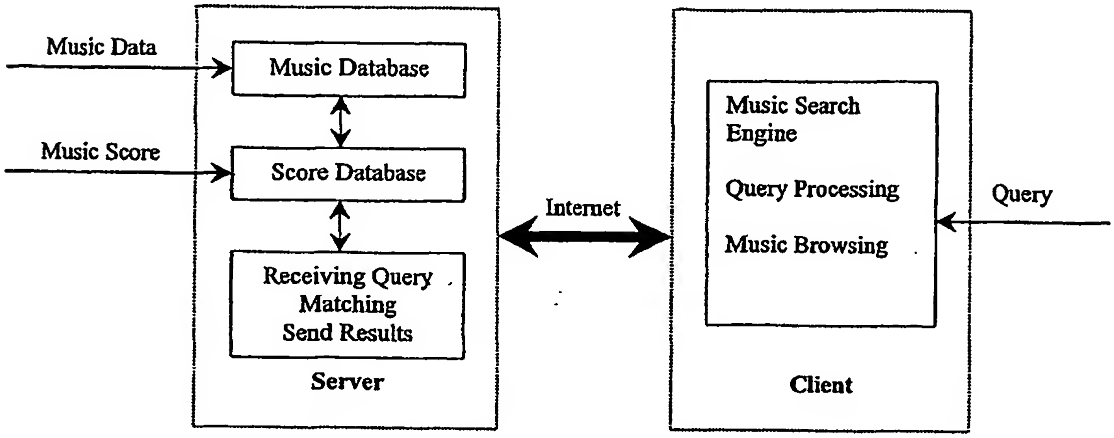


Figure 1: System Architecture

Music Id	Music Title	Singer	Type	Score Keywords	Link To Music Database

Figure 2: Structure of Score Database

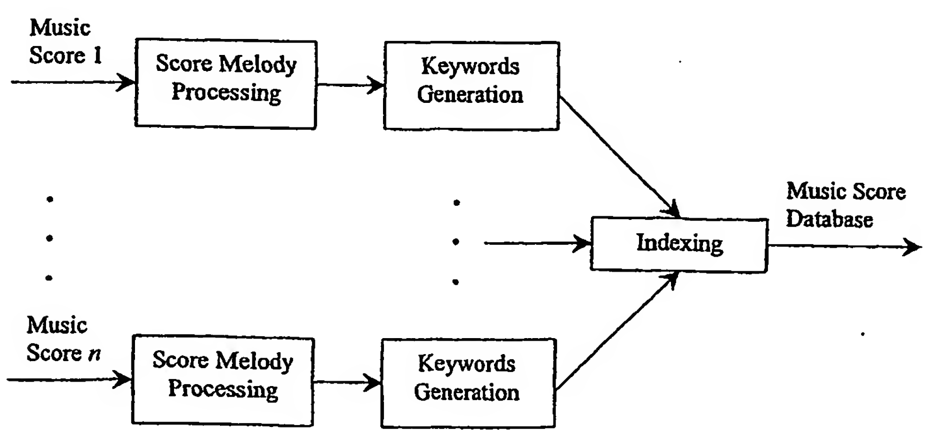


Figure 3: Music Score Database Construction

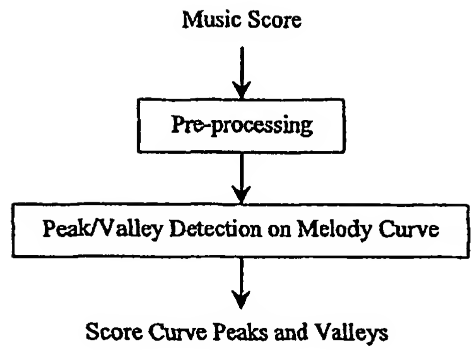


Figure 4: Score Melody Processing

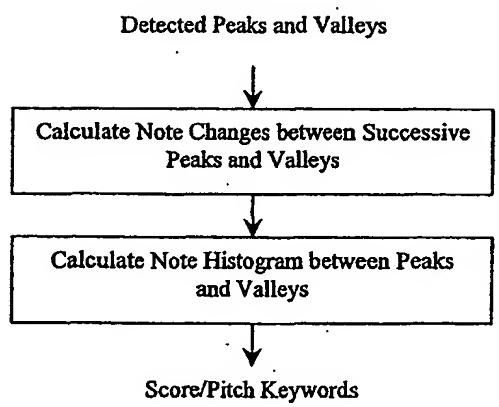


Figure 5: Keywords Generation

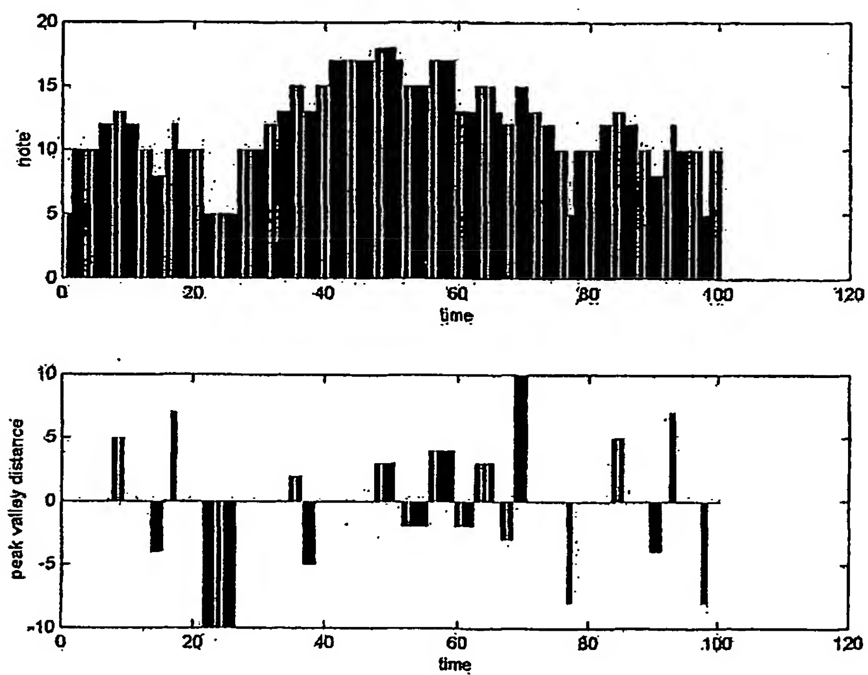


Figure 6 (a): Score Melody Processing

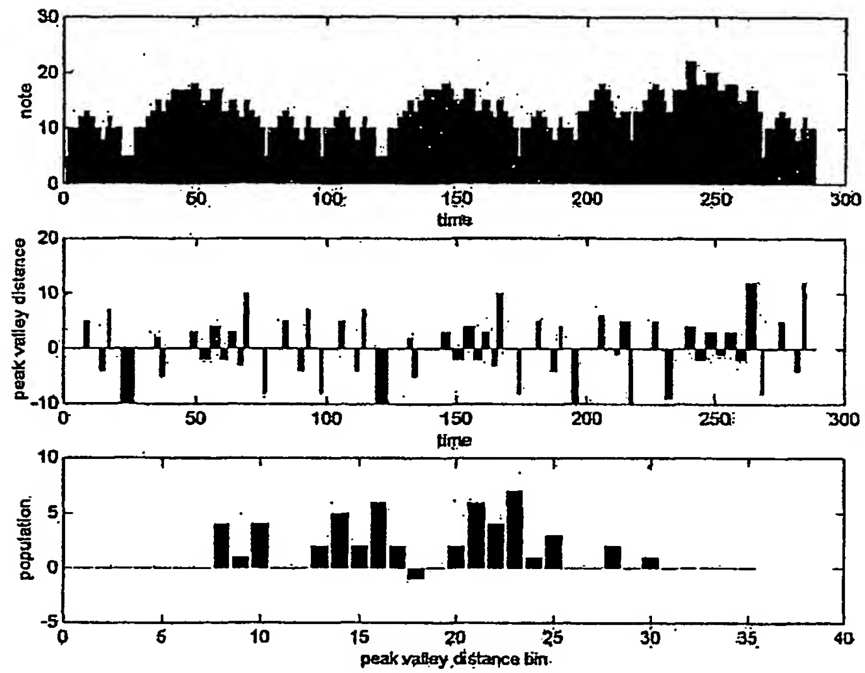


Figure 6 (b): Score Melody Processing for a Complete Song

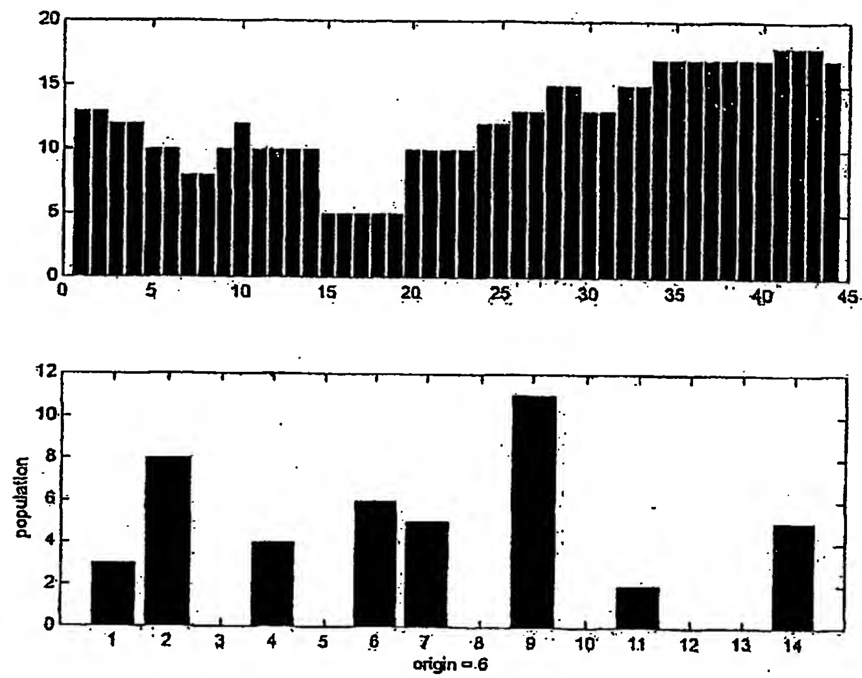


Figure 6 (c): Score Note Histogram

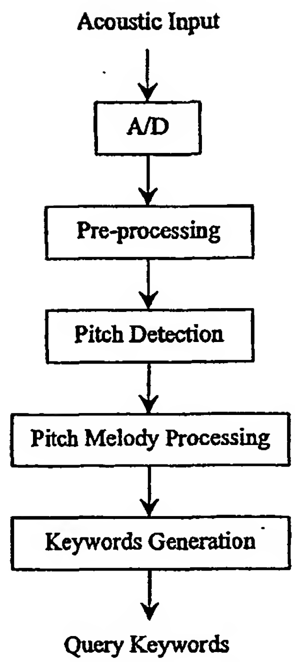


Figure 7: Query Processing

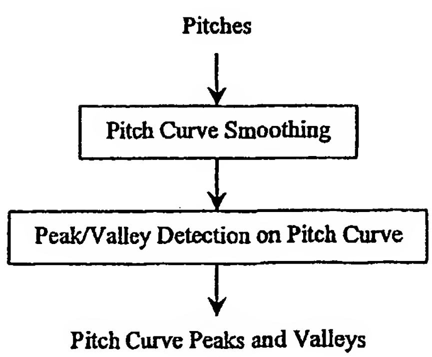


Figure 8: Pitch Melody Processing

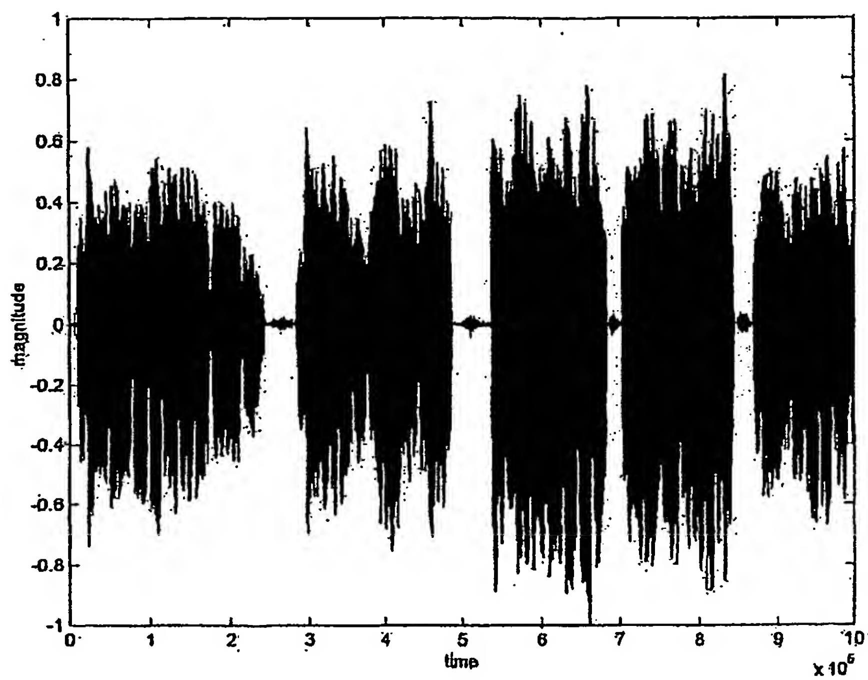


Figure 9 (a): Waveform of a humming query

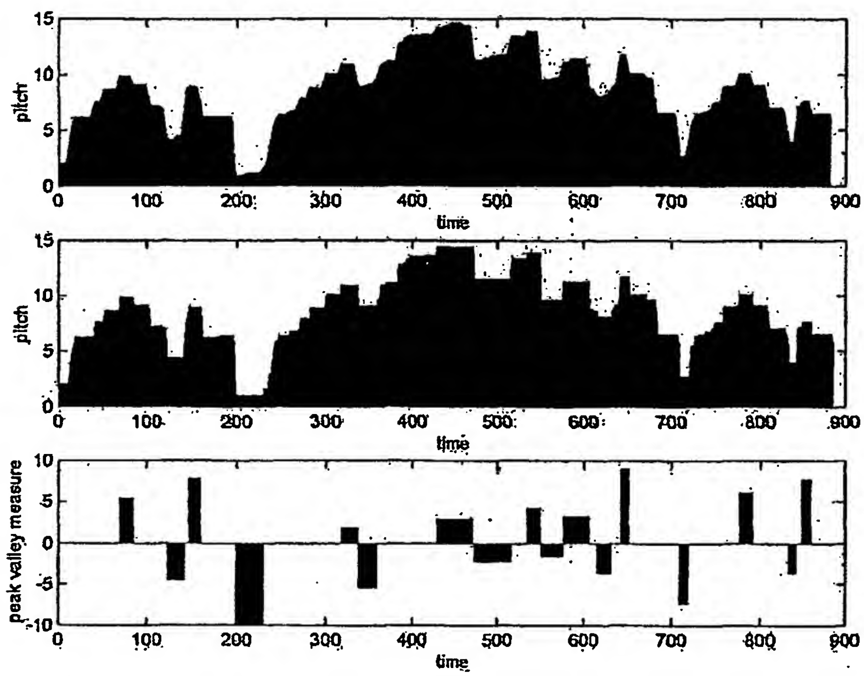


Figure 9 (b): Pitch Melody Processing

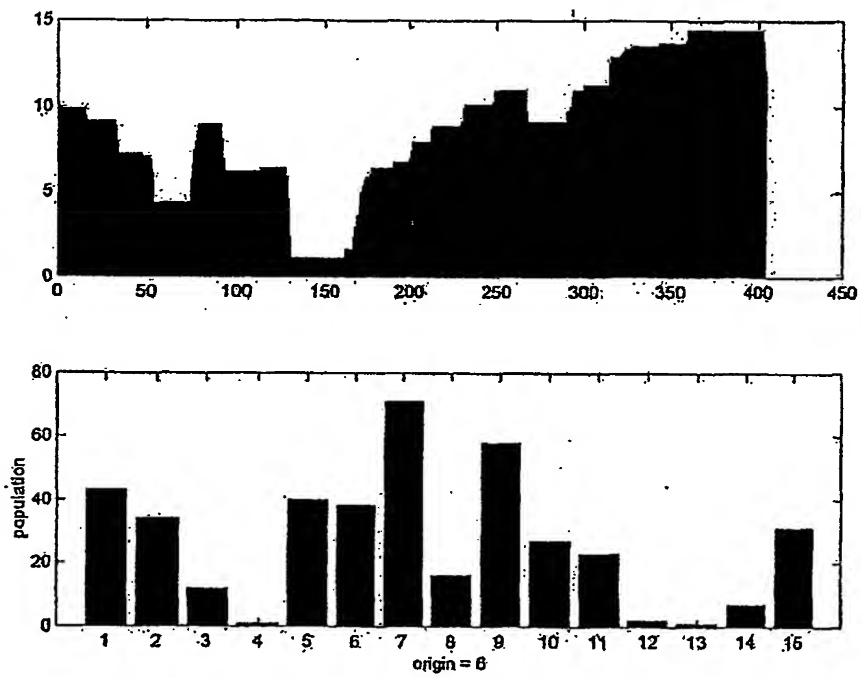


Figure 9 (c): Pitch Keyword Generation

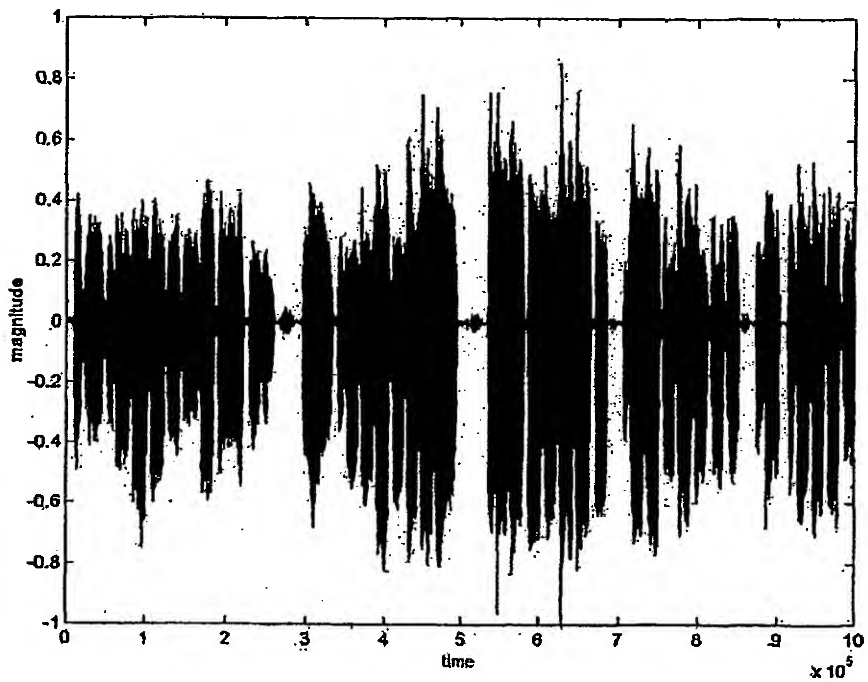


Figure 10 (a): Waveform of a second humming query

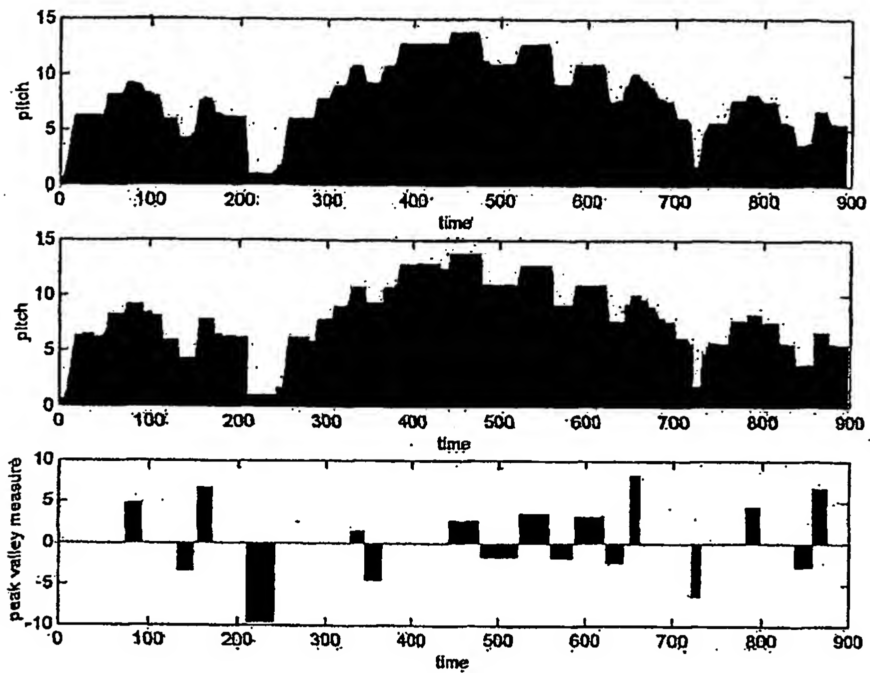


Figure 10 (b): Pitch Melody Processing

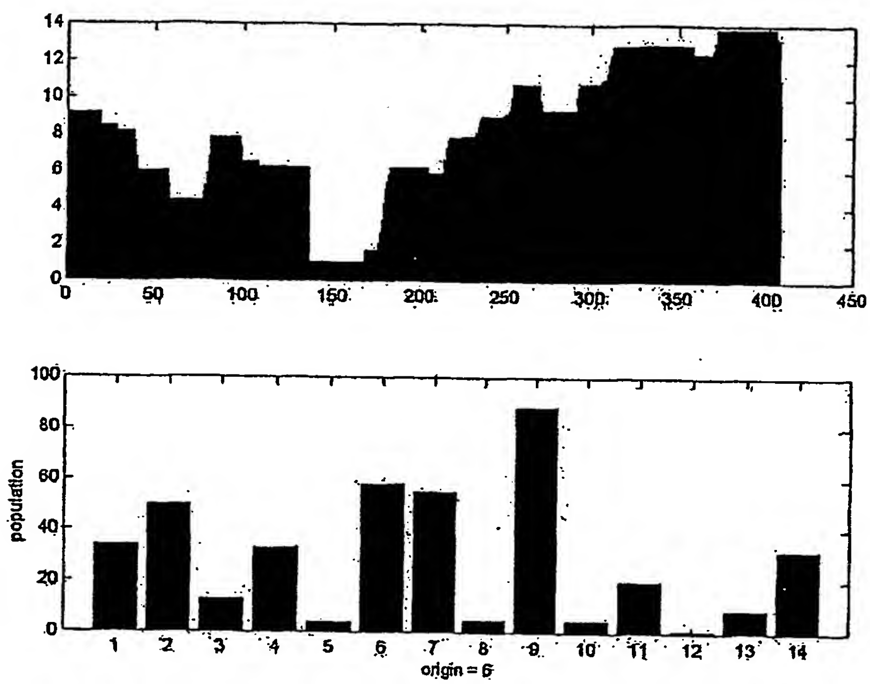


Figure 10 (c): Pitch Keyword Generation

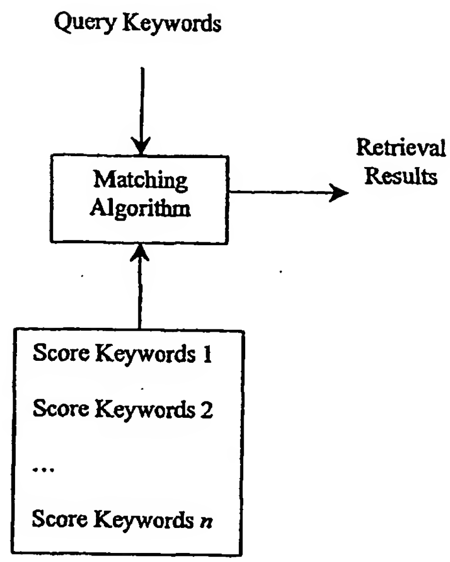


Figure 11: Song Search by Keywords Matching

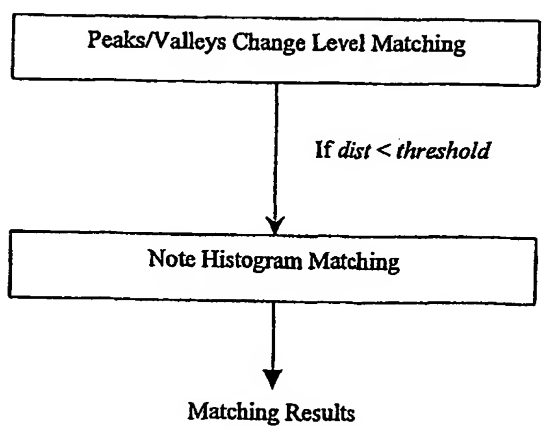


Figure 12: Keywords Matching